AIR LIQUIDE ADVANCED TECHNOLOGIES	**PROCES-VERBAL D'ESSAI** ***TEST REPORT*** **CRYOGENIC TURBO EXPANDER**	**N° : C4058-NT-18 (1)** Folio : 1 / 11

AFFAIRE : **RHEA** *JOB* :	N° : 301 0914 *N° :*	Fiche Suiveuse n° : *Inspection traveller n° :*
Identification du matériel : **C6 593 HI$_1$** N° : 324-XT004 *Material identification* :	Quantité / *Quantity* : 1 Lot / *Batch* :	

Fournisseur/Fabricant : *Supplier / Manufacturer :* **AIR LIQUIDE**	Organisme de Contrôle : *Inspected by :* **DTEC**	Lieu : *Location :* **Sassenage**	Phase : *Phase :*

Documents de référence : *Reference documents :* PROCEDURE : **D4444-PO-2**	Instruments de contrôles utilisés : *Inspection instruments used :*	
	Type / *Type*	N° de Gestion/*Control n°*
	Test bed	**504 9999 100**

MESURES	**RESULTATS**	**OBSERVATIONS**
PIVOTERIE / *BEARINGS*	Pass	
VITESSES CRITIQUES *Critical speeds*	Pass	
SURVITESSE / *Overspeeds*	Pass	
DESCENTE EN FROID *Cold down*	Pass	Limited by the test bench
RENDEMENT / *Efficiency*	Pass	Limited by the test bench

DECISION : *DECISION :* **CONFORME** / *PASS* ☑ **NON CONFORME** / *FAIL* ☐	**OBSERVATIONS :** *COMMENTS :*

	ESSAI / *TEST*	**Responsable / *Manager***	**A.Q. / *Q.A.***		
NOM / *NAME*	R. Guimaraes	F. Delcayre			
DATE / *DATE*	25/11/2013	25/11/2013			
SIGNATURE / *VISA*					

CONTENTS

1. SCOPE

This report is a summary of the tests of a Cryogenic turbo-expander cartridge, performed on DTA test bed according to the procedure D4444-PO-2.

2. PROCESS CONDITION

The data sheet in appendix gives the turbine process conditions specified by the customer.

3. GAS USED FOR THE TEST

☑Helium ☐Nitrogen

4. BEARING CONDITIONS

The diagrams in appendix give the gas bearing conditions :

- to be applied on site,

- to be applied during the test.

5. ANNEXES

TESTS REPORTS

5.1 THRUST BEARING TEST, LOW SPEED

(Items 6.1 of procedure)

Cartridge number: C6 593 HI_1
Bearing conditions required: NORMAL

CASE	EXTREME 1	EXTREME 2	
INPUTS			
Load	0	826	N
On	Brake	Turbine	Bearing
Equivalent pressure difference on the shaft	0	26	10^5Pa
OUTPUTS			
Inlet bearing pressure	15.22	15.55	10^5Pa
Outlet bearing pressure	2.78	2.90	10^5Pa
Turbine outlet pressure (1)	2.91	2.99	10^5Pa
Brake pressure (2)	2.87	17.60	14.04
Pressure difference = (2) – (1)	-0.04	14.61	10^5Pa
Speed	12	9	H_Z
Passed/failed	passed	passed	

TEST REPORT

5.2 THRUST AND JOURNAL BEARINGS TEST, HIGH SPEED

(Items 6.2 of procedure)

Cartridge number: C6 593 HI_1
Bearing conditions required: NORMAL

MODE	MINIMAL	NOMINAL	MAXIMAL	
INPUTS				
Turbine outlet design pressure (1)	5.7	4.9	3.5	10^5Pa
Brake design pressure (2)	8.8	11	14.3	10^5Pa
Δ = 2-1	3.1	6.1	10.8	10^5Pa
OUTPUTS				
Inlet bearing pressure	15.06	15.07	15.09	10^5Pa
Outlet bearing pressure	3.01	2.88	2.82	10^5Pa
Turbine outlet test pressure (1)	3.45	3.35	3.32	10^5Pa
Brake test pressure (2)	6.69	9.53	14.17	10^5Pa
Δ = (2) – (1)	3.24	6.18	10.85	10^5Pa
Speed	1198	1017	837	Hz
Passed/failed	passed	passed	passed	

TEST REPORT

5.3 THRUST AND JOURNAL BEARING TEST, HIGH SPEED

(Items 6.2 of procedure)

Cartridge number: C6 593 HI_1
Bearing conditions required: ALARM AND STOP

BEARING CONDITIONS	**ALARM**	**STOP**	
Mode	Nominal	Nominal	
INPUTS			
Turbine design outlet pressure (1)	4.9	4.9	10^5Pa
Brake design pressure (2)	11	11	10^5Pa
Δ = 2-1	6.1	6.1	10^5Pa
OUTPUTS			
Inlet bearing pressure		14.01	10^5Pa
Outlet bearing pressure		2.83	10^5Pa
Turbine outlet test pressure		3.18	10^5Pa
Brake outlet pressure		5.21	10^5Pa
Δ = 2-1		2.03	10^5Pa
Speed		1249	Hz
Passed/failed		passed	

TEST REPORT

5.4 CRITICAL SPEEDS AND SHAFT VIBRATIONS

(Items 6.3 of procedure)

Cartridge number: C6 593 HI_1
Bearing conditions required: STOP

INPUTS					
	1st RIGID MODE		2nd RIGID MODE		
Calculated peak freq.	550		750		H_z
OUTPUTS					
Measured critical speeds	BEGIN.	END	BEGIN.	END	
	600			700	H_z
Sound level estimation	B		B		
Time within the mode (> 3 ‘)	3		3		Min
Inlet bearing pressure	15.07		15.07		10^5Pa
Outlet bearing pressure	2.88		2.88		10^5Pa
Passed/failed	passed		passed		

Sound level estimation:

A: Inaudible B: Perceptible C: Noisy D: Excessive

TEST REPORT

5.5 OVERSPEED TEST

(Items 6.4 of procedure)

Cartridge number: C6 593 HI_1
Bearing conditions required: NORMAL

INPUTS		
Nominal speed (Hz)	Maximum speed (Hz)	Over speed (Hz)
1250	1350	1380
OUPUTS		

BEARING TEST CONDITIONS

BEARING GAS PRESSURE (10^5Pa)		BEARING GAS TEMPERATURE (°C)		BEARING GAS FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
15.06	2.81	16.4	24.7	19.2

TURBINE TEST CONDITIONS

TURBINE PRESSURE (10^5Pa)		TURBINE TEMPERATURE (K)		TURBINE FLOW RATE (g/s)
SUPPLY	RETURN	SUPPLY	RETURN	
14.24	3.24	243.87	197.09	179.71

BRAKE TEST CONDITIONS

INLET BRAKE PRESSURE 10^5 Pa	OUTLET BRAKE TEMPERATURE °C
4.83	59

TEST RESULTS

ROTATION SPEED H_z	STEADY STATE	OVERSPEED STATE DURATION (mn)	COMMENTS	
			FAIL	PASS
1380	A	3		X

Steady state evaluation:

A: Stable B: Noisy C: Unstable

TEST REPORT

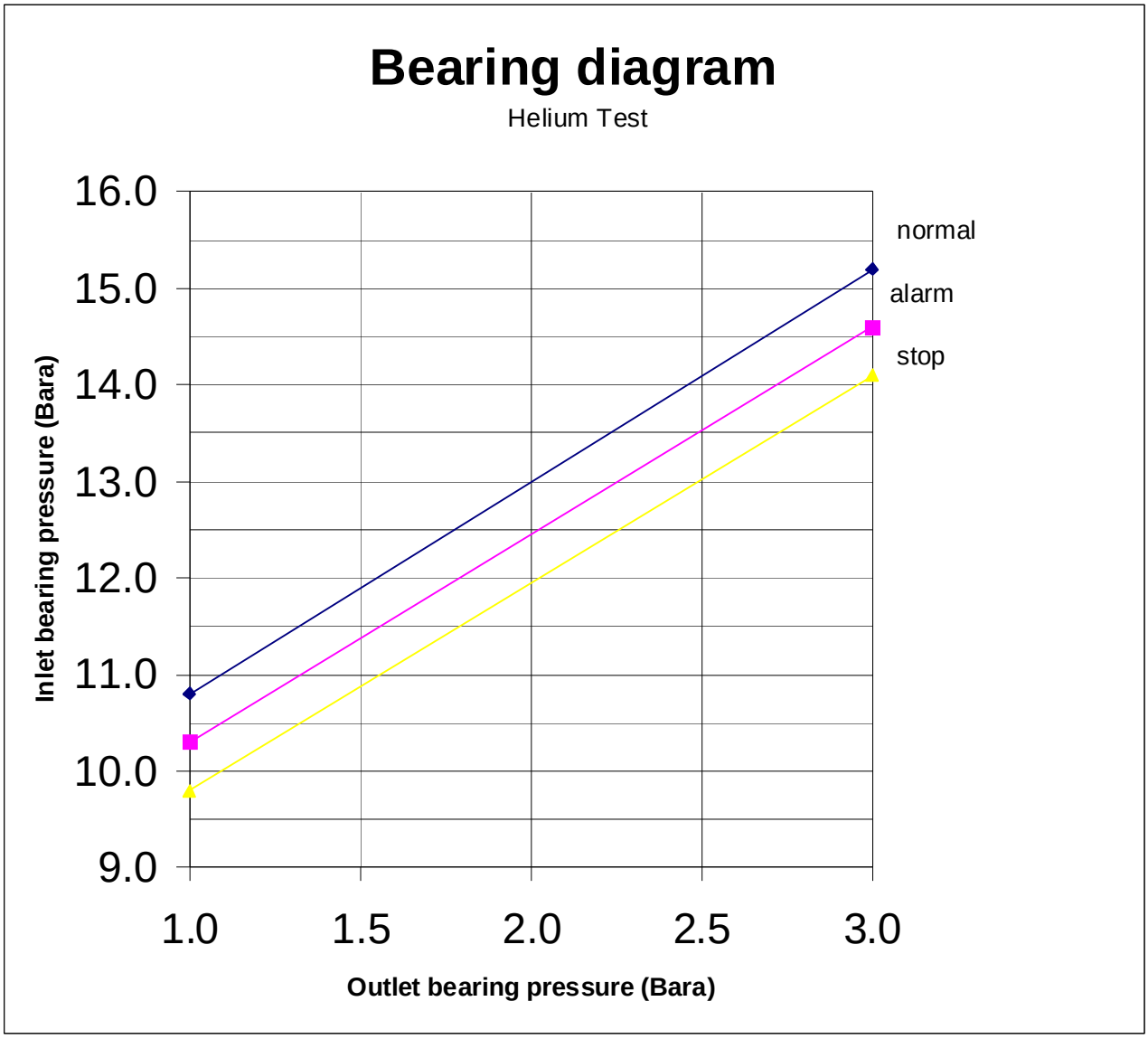
5.6 COOL DOWN, START-UP AND SHUT-DOWN

(Items 6.5 and 6.6 of procedure)

Cartridge number: C6 593 HI_1
Bearing conditions required: normal
Nominal speed:

	AMBIENT	MEDIUM	+10% K	NOMINAL	- 10%	
Target outlet temperature	250	150	21	19	17	K
TURBINE :						
Inlet pressure	6.14	12.58	10.96			10^5Pa
Outlet pressure	2.99	3.14	3.80			10^5Pa
Inlet temperature	269.69	183.46	51.48			K
Outlet temperature	255.92	149.65	39.86			K
Flow	73.33	182.85	296.06			g/s
U1/C0	0.17	0.25	0.42			
µ	25.34	43.65	65.46			%
BRAKE :						
Inlet pressure	4.63	5.16	5.28			10^5Pa
Outlet temperature	4.79	5.56	5.56			°C
BEARING :						
Inlet pressure	15.07	15.14	15.42			10^5Pa
Outlet pressure	2.88	2.80	3.44			10^5Pa
Inlet temperature	16.5	17	17.53			°C
Outlet temperature	20.4	27.7	16.58			°C
Inlet flow	17.85	18.82	18.15			g/s
SPEED :	757	1221	1003			Hz
Number of start up/shut down	3		3			
Fail/pass	passed	passed	passed			

AIR LIQUIDE ADVANCED TECHNOLOGIES	**DIAGRAMME PIVOTERIE** ***GAS BEARING DIAGRAM***	**N° : C4058-NT-18 (1)** Folio : 10 / 11
AFFAIRE / *JOB* : RHEA	N° : 301 0914	
Identification du matériel / *Material identification* : C6 593 HI_1		
APPLICATION : ☑ Site Client/*Customer* ☑ ALAT Test		



TEST REPORT

5.7 EFFICIENCY VERSUS U1/CO

(Items 6.7 of procedure)
Cartridge number: C6 593 HI_1

INPUTS — TURBINE PROCESS CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES K		FLOW kg/s 10^{-3}	ENTHALP. DROP kJ/kg		η	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10^5Pa
	INLET	OUTLET	INLET	OUTLET		Δ Hs	Δ Hr	Δ Hr/ Δ Hs			
He	19.1	4.9	28.6	19.1	987	63.3	49.3	0.78	1250	48600	10.5

OUTPUTS — TURBINE TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES K		FLOW kg/s 10^{-3}	ENTHALP. DROP KJ/kg		η	ROTATION SPEED Hz	REFRIG. POWER Watt	INLET WHEEL PRESS. 10^5Pa
	INLET	OUTLET	INLET	OUTLET		Δ Hs	Δ Hr	Δ Hr/ Δ Hs			
He	10.96	3.80	51.48	39.86	296.06	93.955	61.509	0.654	1003	18210	5.36

BEARING TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	15.42	3.44	17.53	16.58

BRAKE TEST CONDITIONS

GAS	PRESSURES 10^5Pa		TEMPERATURES °C	
	INLET	OUTLET	INLET	OUTLET
He	5.28	5.56	30.8	41.6

TEST RESULTS

WHEEL DIAM. mm	TIP VELOCITY U_1 m/s	SPOUTING VELOCITY C_O m/s	U_1/ Co	η %	COMMENTS	
					FAIL	PASS
58.0	182.75	433.48	0.42	65.46		X

UTILITY FLOW RATE

GAS BEARING SUPPLY g / s	BRAKE SUPPLY g / s	SEAL GAS g / s	RETURN g / s
18.15	0	0.22	19.98